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(54) **Method and system for controlling optical amplification in wavelength division multiplex optical transmission**

(57) The present invention relates generally to the field of optical transmission and particularly to a method and a system for controlling optical amplification in wavelength division multiplex optical transmission.

WDM systems currently under development will have eighty or more channels, i. e. modulated optical signals with different wavelengths (known as Dense Wavelength Division Multiplexing, DWDM). These DWDM systems are demanding optical amplifiers which, especially considering the cascading of a plurality of optical amplifiers along the transmission path of the DWDM system, have only very limited tolerances in certain parameters. Among these parameters gain flatness and gain tilt are of special importance.

The present invention discloses a method and a system which make use of auxiliary optical signals having a given power level which is equal for all auxiliary signals. Differences in the power levels of the auxiliary signals after optical amplification are used for the control of the optical amplifiers of the WDM system.

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Descripti n

TECHNICAL FIELD

[0001] The present invention generally relates to the field of optical transmission and particularly to a method and a system for controlling optical amplification in wavelength division multiplex optical transmission.

BACKGROUND OF THE INVENTION

[0002] Wavelength division multiplexing (WDM) is being introduced as a means of increasing the capacity of optical fibre transmission systems. In a WDM system each individual fibre carries a number of optical signals having different wavelengths. When these optical signals are transmitted over long distances, periodic regeneration of the optical signals is necessary. Currently, this amplification is effected either by demultiplexing the different wavelengths and then converting the optical signals to corresponding electrical signals which are regenerated and then reconverted to optical signals or by using optical amplifiers, e. g. Erbium Doped Fibre Amplifiers (EDFA). Optical amplifiers do have the advantage of both relatively low cost and the ability to amplify all used wavelengths without the need for demultiplexing and optoelectronic regeneration.

[0003] WDM systems currently under development will have thirty or more channels, i. e. modulated optical signals with different wavelengths (known as Dense Wavelength Division Multiplexing, DWDM). These DWDM systems are demanding for optical amplifiers which, especially considering the cascading of a plurality of optical amplifiers along the transmission path of the DWDM system, have only very limited tolerances in certain parameters. Among these parameters gain flatness and gain tilt are of special importance. Problems with gain tilt may arise from ageing of the DWDM system, from temperature effects, from different attenuation slopes of fibre used to form the transmission path or from stimulated Raman scattering.

[0004] It is known that gain tilt and gain flatness of the optical amplifiers can be optimised by controlling the input power of the optical amplifier. In EP 0 637 148 A1 a WDM system is described wherein transmitters are used which have means for associating identification signals one with each transmitted wavelength and wherein each optical amplifier of the transmission path has means for determining from the identification signals the number of wavelength present on the transmission path whereby to control the power of the different channels. The use of identification signals for each transmitted wavelength also allows to maintain a power balance between different wavelength channels in order to maintain the necessary gain flatness. This is achieved by determination of the amplitudes of individual identification signals associated with the transmitted wavelengths.

[0005] The known WDM system has the disadvantage of associating an identification signal with each transmitted wavelength channel. In addition it has the disadvantage that in WDM systems it is not guaranteed that every wavelength channel is present all the time. This causes problems if the amplitude of the individual identification signal normally associated with a missing wavelength channel is used to maintain gain flatness as described above.

SUMMARY OF THE INVENTION

[0006] Accordingly, it is an object of the present invention to provide a method and a system for controlling optical amplification in wavelength division multiplex optical transmission. It is one aim of the inventive method under consideration to avoid the drawbacks known from the state of the art.

[0007] According to a first aspect of the invention there is provided a method for controlling optical amplification of an optical transmission signal consisting of a plurality of modulated optical signals with different wavelength for wavelength division multiplex optical transmission, comprising steps of

- adding a first auxiliary optical signal having a given power level at a wavelength shorter than the shortest wavelength of the optical transmission signal,
- adding a second auxiliary optical signal having the same power level as the first auxiliary optical signal at a wavelength longer than the longest wavelength of the optical transmission signal,
- detecting the auxiliary optical signals from the optical transmission signal after optical amplification thereof,
- controlling the optical amplification of the optical transmission signal depending on the difference between the power levels of the detected auxiliary optical signals.

[0008] According to a second aspect of the invention there is provided a system for controlling optical amplification of an optical transmission signal consisting of a plurality of modulated optical signals with different wavelength for wavelength division multiplex optical transmission, formed by at least one means for combining optical signals, with

- a first means connected to the means for combining optical signals producing a first auxiliary optical signal having a given power level at a wavelength shorter than the shortest wavelength of the optical transmission signal,
- a second means connected to the means for combining optical signals producing a second auxiliary optical signal having the same power level as the first auxiliary optical signal at a wavelength longer than the longest wavelength of the optical transmiss-

sion signal,

a third means for detecting the auxiliary optical signals from the optical transmission signal and determining the power levels of the auxiliary optical signals after optical amplification thereof with an optical amplifier,

a controlling means controlling the optical amplifier depending on the difference between the power levels of the auxiliary optical signals.

[0009] An advantage of the present invention is that the method and system described herein are insensitive to the absence of wavelength channels, e. g. the failure of certain wavelengths or optical signals forming the optical transmission signal. It is an other advantage of the present invention, that it allows to reduce the number of identification signals necessary.

[0010] The present invention will become more fully understood from the detailed description given hereinafter and further scope of applicability of the present invention will become apparent. However, it should be understood that the detailed description is given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The following detailed description is accompanied by drawings of which

- Fig. 1 is a schematic representation of a first embodiment of a wavelength division multiplex system according to this invention,
- Fig. 2 is a schematic representation of a second embodiment of a wavelength division multiplex system according to this invention,
- Fig. 3 is a schematic representation of a first embodiment of a controlled optical amplifier according to this invention,
- Fig. 4 is a schematic representation of a second embodiment of a controlled optical amplifier according to this invention,
- Fig. 5 is a schematic representation of a third embodiment of a controlled optical amplifier according to this invention,
- Fig. 6 is a schematic representation of a fourth embodiment of a controlled optical amplifier according to this invention, and
- Fig. 7 shows the power levels of optical signals and auxiliary optical signals according to this invention.

[0012] Identical denotations in different Figures represent identical elements. Bold lines connecting the depicted elements of the figures represent optical connections, e. g. with optical fibres, other connections are electrical connections.

DETAILED DESCRIPTION

[0013] Depicted in Fig. 1 is a first embodiment of the present invention, comprising a wavelength division multiplex optical transmission system. It comprises a means for combining optical signals M, e. g. a wavelength division multiplexer, which forms an optical transmission signal of modulated optical signals $\lambda_1 \dots \lambda_n$ at different wavelengths and connected to the inputs of the wavelength division multiplexer M.

[0014] Connected to two additional inputs are means λ_{a1} and λ_{a2} for producing auxiliary optical signals, e. g. lasers. The wavelength of the first laser λ_{a1} is shorter than the shortest wavelength used in the WDM system. The wavelength of the second laser λ_{a2} is longer than longest wavelength used in the WDM system. The power level of the auxiliary optical signals produced by the lasers λ_{a1} and λ_{a2} is equal. The auxiliary optical signals are combined by the wavelength division multiplexer M with the optical signals $\lambda_1 \dots \lambda_n$ to form the optical transmission signal which is available at the output of the wavelength division multiplexer M. Referring to Fig. 7, the power level P_a of the auxiliary optical signals λ_{a1} and λ_{a2} may be lower than the power level P_o of the optical signals $\lambda_1 \dots \lambda_n$ to not influence the power budget of the WDM system.

[0015] It is also possible to add the auxiliary optical signals with an additional means for combining optical signals, e. g. directly after wavelength division multiplexer M, with the help of a coupler or a circulator, or at any other position of the transmission path. To achieve the best results it is advantageous to add the auxiliary optical signals at the beginning of the transmission path.

[0016] The optical transmission signal is fed to an input I of a controlled optical amplifier A which amplifies the optical transmission signal. The amplified optical transmission signal is available at an output O of the controlled amplifier A. The transmission signal is then transmitted through an optical fibre F. After a certain fibre length, e. g. 100 km, another controlled optical amplifier A is connected to the optical fibre F. Many stages comprising an optical fibre F and a controlled amplifier A may follow as indicated by denomination Z. Finally a demultiplexer and receivers for the optical transmission signal are connected to the system. For reason of clarity the demultiplexer and the receivers are not shown.

[0017] The principle of the present invention is shown in Fig. 7. The power levels of the auxiliary optical signals λ_{a1} and λ_{a2} were equal at P_a when they were added to the optical transmission signal $\lambda_1 \dots \lambda_n$, they should be equal after optical amplification, too. If a difference in

the power levels of the auxiliary optical signals is present after amplification, e. g. for as shown with a dashed line for the second auxiliary optical signal λ_{a2} having a power level of P_{a2} , gain tilt has to be corrected. This can be effected with the controlled optical amplifier A. The difference of the power levels of the auxiliary optical signals ($P_{a1} - P_{a2}$) is an unambiguous measure for the slope of a line L_2 passing through the power level of the auxiliary signals of the first and second auxiliary optical signal λ_{a1} and λ_{a2} .

[0018] Depicted in Fig. 2 is a second embodiment of the present invention, comprising a wavelength division multiplex optical transmission system which is identical to the system as shown in Fig. 1 and explained above. In difference to Fig. 1 an additional means λ_{ax} for producing an auxiliary optical signal, e. g. a laser, is added. The wavelength of the auxiliary optical signal produced by laser λ_{ax} can range from the shortest to the longest wavelength of the optical transmission signal of the WDM system. It is advantageous to choose a wavelength which is not used by optical signals of the WDM system, as shown in Fig. 7. It is also possible to use a wavelength normally used in the WDM systems by an optical signal for the auxiliary optical signal which then substitutes the optical signal. It is also possible to use more than one additional auxiliary signal within the bandwidth of the optical transmission signal of the WDM system. The power level of the auxiliary optical signal produced by laser λ_{ax} equals the power level of the auxiliary optical signals described above. With additional auxiliary optical signals it is also possible to control gain flatness.

[0019] Depicted with dashed lines in Fig. 1 and 2 are pilot tone generators T_1 , T_2 and T_x connected to the lasers λ_{a1} , λ_{a2} and λ_{ax} . The auxiliary optical signals produced by the lasers λ_{a1} , λ_{a2} and λ_{ax} are modulated with the pilot tones from the generators T_1 , T_2 and T_x . The pilot tones, which have different, individual frequencies, are used for detecting the power of the auxiliary optical signals by their amplitudes and will be explained with reference to Fig. 3 and 4.

[0020] Depicted in Fig. 3 is a first embodiment of a controlled optical amplifier A, as described above, with an input I and an output O for the optical transmission signal. This first embodiment uses the pilot tones described above. The controlled optical amplifier A comprises an optical amplifier OA, means 3, TD for detecting the pilot tones modulated to the auxiliary optical signals from the optical transmission signal after amplification of the optical transmission signal and a controlling means C to control the optical amplifier OA. The input I of the controlled optical amplifier A forms the input of the optical amplifier OA which is optically connected to the input of means 3 for detecting the auxiliary optical signals. The output of means 3 forms the output O of the controlled optical amplifier A.

[0021] The means 3 for detecting the auxiliary optical signals comprises a tap coupler TC and a photo detec-

tor PD. The tap coupler TC is connected to the output of the optical amplifier OA and is coupling out a small amount of the energy of the optical transmission signal. The out coupled optical transmission signal is fed to the photo

[0022] As the auxiliary optical signals were modulated with the individual pilot tones, as described above, the electrical signal contains the different frequencies of the pilot tones used. With the help of a pilot tone detection circuit TD the different pilot tones can be detected. A controlling means C forms the difference of the power levels from the auxiliary signals. If there is no difference or a difference smaller than a given threshold no corrections are necessary. If there is a difference or the given threshold is exceeded the controlling means C corrects the optical amplifier OA until the measured difference vanishes. The correction of the optical amplifier OA can be achieved by controlling the inversion, e. g. by controlling the pump power of the optical amplifier OA or by using a variable optical attenuator within the optical amplifier OA. The correction of an optical amplifier is described in more detail for example in EP 0 782 225 A2.

[0023] To avoid negative effects to optical amplifiers used in the WDM system the frequencies of the pilot tones used should be higher than the reciprocal of the time constant of optical amplifiers used. In addition it has to be avoided that spectral parts of the optical transmission signals of the WDM system overlap with pilot tone frequencies. If the optical transmission signal is optically separated, as will be explained afterwards, no spectral problems arise.

[0024] Depicted in Fig. 4 is a second embodiment of a controlled optical amplifier A, as described above, with an input I and an output O for the optical transmission signal. This second embodiment uses the pilot tones described above. The controlled optical amplifier A comprises an optical amplifier OA, means 3, TD for detecting the pilot tones modulated to the auxiliary optical signals from the optical transmission signal after amplification of the optical transmission signal and a controlling means C to control the optical amplifier OA. The input I of the controlled optical amplifier A forms the input of the optical amplifier OA which is optically connected to the input of means 3 for detecting the auxiliary optical signals. The output of means 3 forms the output O of the controlled optical amplifier A.

[0025] The means 3 for detecting the auxiliary optical signals comprises a tap coupler TC, a power splitter PS, gratings G1 and G2 and a photo detector PD. The tap coupler TC is connected to the output of the optical amplifier OA and is coupling out a small amount of the energy of the optical transmission signal. The out coupled optical transmission signal is fed to a first port of the power splitter PS. To a second port of the power splitter PS gratings G1 and G2, e. g. Bragg- or fibre-Bragg-gratings, are connected in series. Grating G1 is a reflector for the auxiliary optical signal of laser λ_{a1} , grat-

ing G2 is a reflector for the auxiliary optical signal of laser λ_{a2} . The reflected auxiliary signals are available at a third port of the power splitter PS. At a fourth port M of the power splitter PS the output power of the optical amplifier OA is available and could be monitored. The third port of the power splitter PS is connected to the photo detector PD which transforms the auxiliary optical signals to an electrical signal. As the auxiliary optical signals were modulated with the individual pilot tones, as described above, the electrical signal contains the different frequencies of the pilot tones used. With the help of a pilot tone detection circuit TD the different pilot tones can be detected. A controlling means C forms the difference of the power levels from the auxiliary signals. If there is no difference or a difference smaller than a given threshold no additional corrections are necessary. If there is a difference or the difference exceeds the given threshold the controlling means C corrects the optical amplifier OA until the measured difference vanishes. The correction of the optical amplifier OA can be achieved by controlling, e. g. the pump power of the optical amplifier OA. The correction of an optical amplifier is described in more detail for example in EP 0 782 225 A2.

[0026] Fig. 5 depicts a third embodiment of a controlled optical amplifier A according to the present invention. The controlled amplifier A is detecting the auxiliary optical signals by optical means. Therefore the use of pilot tone generators as shown in Fig. 1 and 2 by dashed lines is not necessary. The controlled optical amplifier A comprises an optical amplifier OA, means 3 for detecting the auxiliary optical signals from the optical transmission signal after amplification of the optical transmission signal and a controlling means C to control the optical amplifier OA. The input I of the controlled optical amplifier A forms the input of the optical amplifier OA which is optically connected to the input of means 3 for detecting the auxiliary optical signals. The output of means 3 forms the output O of the controlled optical amplifier A.

[0027] The means 3 for detecting the auxiliary optical signals comprises a tap coupler TC, a power splitter PS, gratings G1 and G2, a wavelength division multiplexer W and photo detectors PD1 and PD2. The tap coupler TC is connected to the output of the optical amplifier OA and is coupling out a small amount of the energy of the optical transmission signal. The out coupled optical transmission signal is fed to a first port of the power splitter PS. To a second port of the power splitter PS gratings G1 and G2, e. g. Bragg- or fibre-Bragg-gratings, are connected in series. Grating G1 is a reflector for the auxiliary optical signal of laser λ_{a1} , grating G2 is a reflector for the auxiliary optical signal of laser λ_{a2} . The reflected auxiliary signals are available at a third port of the power splitter PS. At a fourth port M of the power splitter PS the output power of the optical amplifier OA is available and could be monitored. The third port of the power splitter PS is connected to the wave-

length division multiplexer W which separates the auxiliary optical signals which are then fed to the photo detectors PD1 and PD2 which transform the auxiliary optical signals to electrical signals. A controlling means C forms the difference of the power levels from the electrical auxiliary signals made available by photo detectors PD1 and PD2. If there is no difference or a difference smaller than a given threshold no additional corrections are necessary. If there is a difference or the difference exceeds the given threshold the controlling means C corrects the optical amplifier OA until the measured difference vanishes. The correction of the optical amplifier OA can be achieved by controlling, e. g. the pump power of the optical amplifier OA. The correction of an optical amplifier is described in more detail for example in EP 0 782 225 A2.

[0028] Fig. 6 depicts a fourth embodiment of a controlled optical amplifier A according to the present invention. This controlled amplifier A is detecting the auxiliary optical signals by optical means. Therefore the use of pilot tone generators as shown in Fig. 1 and 2 by dashed lines is not necessary. The controlled optical amplifier A comprises an optical amplifier OA, means 3 for detecting the auxiliary optical signals signal and a controlling means C to control the optical amplifier OA. The input I of the controlled optical amplifier A forms the input of the optical amplifier OA which is optically connected to the input of means 3 for detecting the auxiliary optical signals. The output of means 3 forms the output O of the controlled optical amplifier A.

[0029] The means 3 for detecting the auxiliary optical signals comprises a tap coupler TC, three power splitters PS1, PS2 and PS3, gratings G1 and G2 and photo detectors PD1 and PD2. The tap coupler TC is connected to the output of the optical amplifier OA and is coupling out a small amount of the energy of the optical transmission signal. The out coupled optical transmission signal is fed to a first port of the first power splitter PS1. To a second and third port of the first power splitter PS1 the second and third power splitters PS2 respectively PS3 are connected with a third respectively first port. To a second port of the second power splitter PS2 a grating G1, e. g. Bragg- or fibre-Bragg-grating, is connected. Grating G1 is a reflector for the auxiliary optical signal of laser λ_{a1} . To a second port of the third power splitter PS3 a grating G2, e. g. Bragg- or fibre-Bragg-grating, is connected. Grating G2 is a reflector for the auxiliary optical signal of laser λ_{a2} . The reflected auxiliary optical signal of laser λ_{a1} is available at a first port of the second power splitter PS2 which is connected to the first photo detector PD1. The reflected auxiliary optical signal of laser λ_{a2} is available at a third port of the third power splitter PS3 which is connected to the second photo detector PD2. At fourth ports M1 and M2 of the second and third power splitters PS2 respectively PS3 the output power of the optical amplifier OA is available and could be monitored. A controlling means C forms the difference of the power levels from the electri-

cal auxiliary signals made available by photo detectors PD1 and PD2. If there is no difference or a difference smaller than a given threshold no additional measurements are necessary. If there is a difference or the difference exceeds the given threshold the controlling means C corrects the optical amplifier OA until the measured difference vanishes. The correction of the optical amplifier OA can be achieved by controlling, e. g. the pump power of the optical amplifier OA. The correction of an optical amplifier is described in more detail for example in EP 0 782 225 A2.

[0030] For all above described embodiments of controlled optical amplifiers A it should be noted, that if, as depicted in Fig. 2, additional auxiliary optical signals λ_{ax} are applied, additional elements like gratings or photo detectors have to be present in the means 3 for detecting the auxiliary optical signals.

Claims

1. Method for controlling optical amplification of an optical transmission signal consisting of a plurality of optical signals ($\lambda_1 \dots \lambda_n$) modulated with different wavelength for wavelength division multiplex optical transmission, comprising steps of
 - adding a first auxiliary optical signal (λ_{a1}) having a given power level at a wavelength shorter than the shortest wavelength of the optical transmission signal,
 - adding a second auxiliary optical signal (λ_{a2}) having the same power level as the first auxiliary optical signal (λ_{a1}) at a wavelength longer than the longest wavelength of the optical transmission signal,
 - detecting the auxiliary optical signals ($\lambda_{a1}, \lambda_{a2}$) from the optical transmission signal after optical amplification thereof,
 - controlling the optical amplification of the optical transmission signal depending on the difference between the power levels of the detected auxiliary optical signals ($\lambda_{a1}, \lambda_{a2}$).
2. Method according to claim 1, characterised by adding at least one other auxiliary optical signal (λ_{ax}) having the given power level at a wavelength ranging from the shortest to the longest wavelength of the optical transmission signal.
3. Method according to claim 2, characterised by adding the at least one other auxiliary optical signal (λ_{ax}) at a wavelength not used for the modulation of optical signals.
4. Method according to claim 2, characterised by adding the at least one other auxiliary optical signal (λ_{ax}) instead of an optical signal at a wavelength thereof.
5. Method according to one of the claims 1 to 4, characterised by modulating each of the auxiliary optical signals ($\lambda_{a1}, \lambda_{a2}, \lambda_{ax}$) with a individual tone (T_1, T_2, T_x).
6. System for controlling optical amplification of an optical transmission signal consisting of a plurality of optical signals ($\lambda_1 \dots \lambda_n$) modulated with different wavelength for wavelength division multiplex optical transmission, formed by at least one means for combining optical signals (M), with
 - a first means (λ_{a1}) connected to the means for combining optical signals (M) producing a first auxiliary optical signal having a given power level at a wavelength shorter than the shortest wavelength of the optical transmission signal,
 - a second means (λ_{a2}) connected to the means for combining optical signals (M) producing a second auxiliary optical signal having the same power level as the first auxiliary optical signal at a wavelength longer than the longest wavelength of the optical transmission signal,
 - a third means (3;TD) for detecting the auxiliary optical signals from the optical transmission signal and determining the power levels of the auxiliary optical signals after optical amplification thereof with an optical amplifier (OA),
 - a controlling means (C) controlling the optical amplifier (OA) depending on the difference between the power levels of the auxiliary optical signals.
7. System according to claim 6, characterised by at least one additional means (λ_{ax}) connected to the means for combining optical signals (M) having the given power level at a wavelength ranging from the shortest to the longest wavelength of the optical transmission signal.
8. System according to claim 7, characterised in that the at least one other auxiliary optical signal (λ_{ax}) has a wavelength not used for the modulation of optical signals.
9. System according to claim 7, characterised in that the at least one other auxiliary optical signal (λ_{ax}) has a wavelength of an optical signal.
10. System according to one of the claims 6 to 9, characterised in that the means for combining optical signals (M) comprises a wavelength division multiplexer.
11. System according to one of the claims 6 to 10, characterised in that a pilot tone generator (T_1, T_2, T_x) is connected to each means ($\lambda_{a1}, \lambda_{a2}, \lambda_{ax}$) for producing the auxiliary optical signals to modulate each of

the auxiliary optical signals with an individual pilot tone.

12. System according to claim 11, characterised in that the means for detecting the auxiliary optical signals 5 3 comprises

- a coupler (TC) connected to the output of the optical amplifier (OA),
- a power splitter (PS) connected to the coupler (TC), 10
- wavelength selective reflectors (G1,G2), connected to the power splitter (PS), for reflecting the auxiliary optical signals,
- a photo detector (PD) connected to the power splitter (PS), and 15
- a pilot tone detector (TD) for detecting the auxiliary signals.

13. System according to claim 11, characterised in that the means for detecting the auxiliary optical signals 20 3 comprises

- a coupler (TC) connected to the output of the optical amplifier (OA), 25
- a photo detector (PD) connected to the power splitter (PS), and
- a pilot tone detector (TD) for detecting the auxiliary signals.

14. System according to one of the claims 6 or 10, characterised in that the means for detecting the auxiliary optical signals 3 comprises 30

- a coupler (TC) connected to the output of the optical amplifier (OA), 35
- a power splitter (PS) connected to the coupler (TC),
- wavelength selective reflectors (G1,G2), connected to the power splitter (PS), for reflecting the auxiliary optical signals, 40
- a wavelength division multiplexer (W) for separating the auxiliary optical signals,
- photo detectors (PD1,PD2) connected to the wavelength division multiplexer (W). 45

15. System according to one of the claims 6 or 10, characterised in that the means for detecting the auxiliary optical signals 3 comprises 50

- a coupler (TC) connected to the output of the optical amplifier (OA),
- a first power splitter (PS1) connected to the coupler (TC),
- additional power splitters (PS2,PS3), connected to the first power splitter (PS1), 55
- wavelength selective reflectors (G1,G2), connected to the additional power splitters

(PS2,PS3), for reflecting the auxiliary optical signals,

- photo detectors (PD1,PD2) connected to the additional power splitters (PS2,PS3).

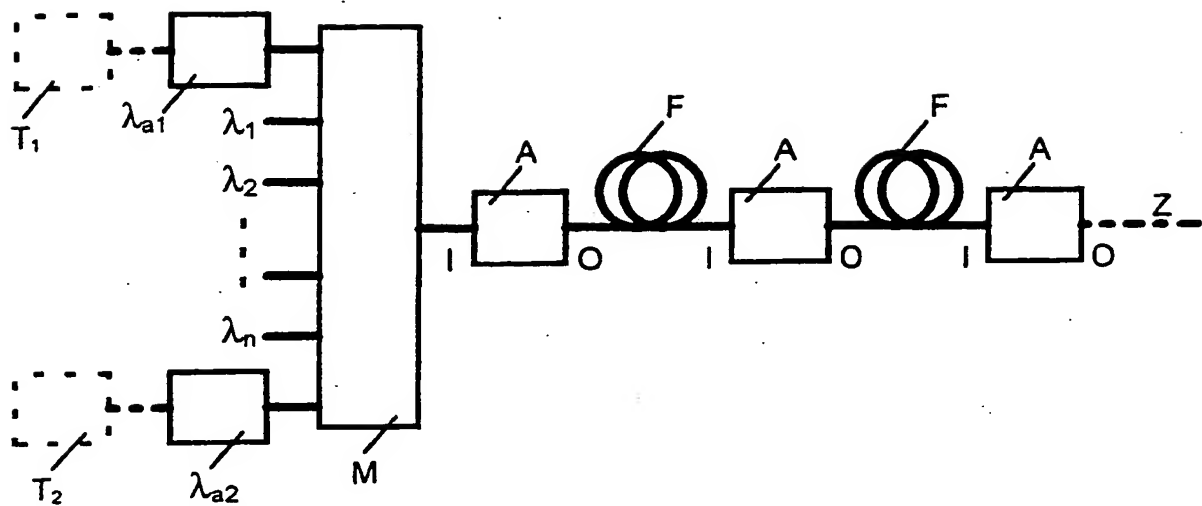


Fig. 1

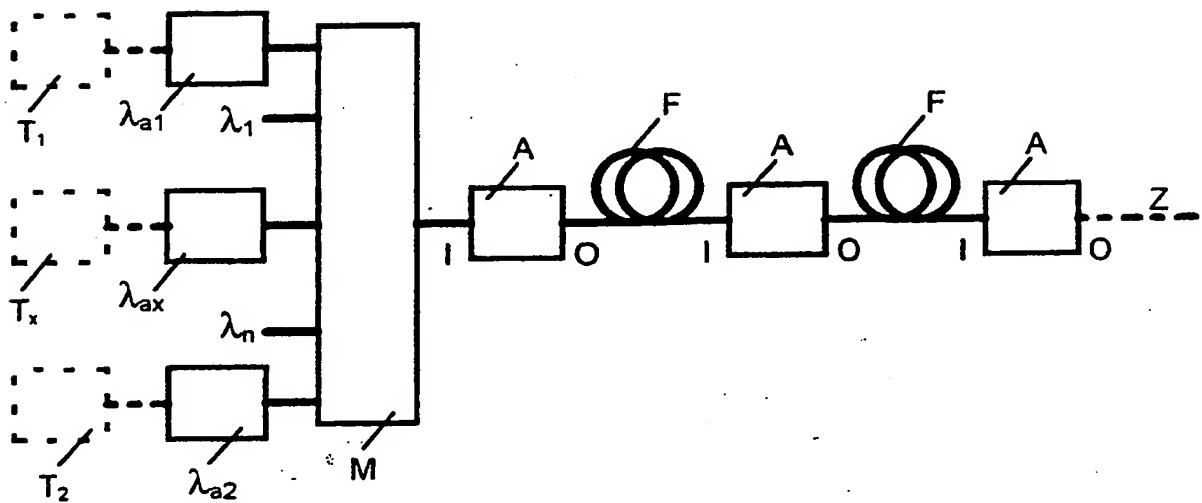


Fig. 2

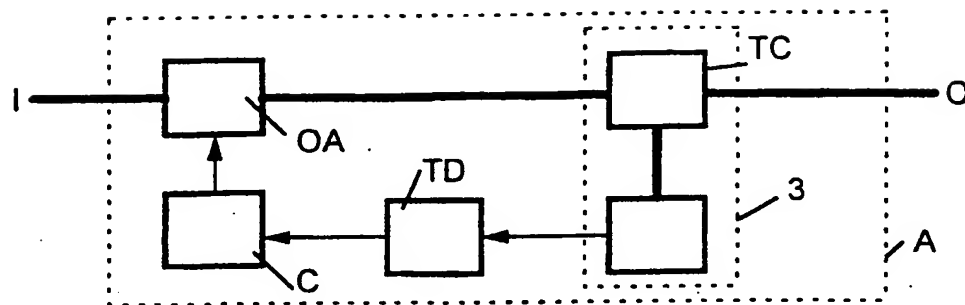


Fig. 3

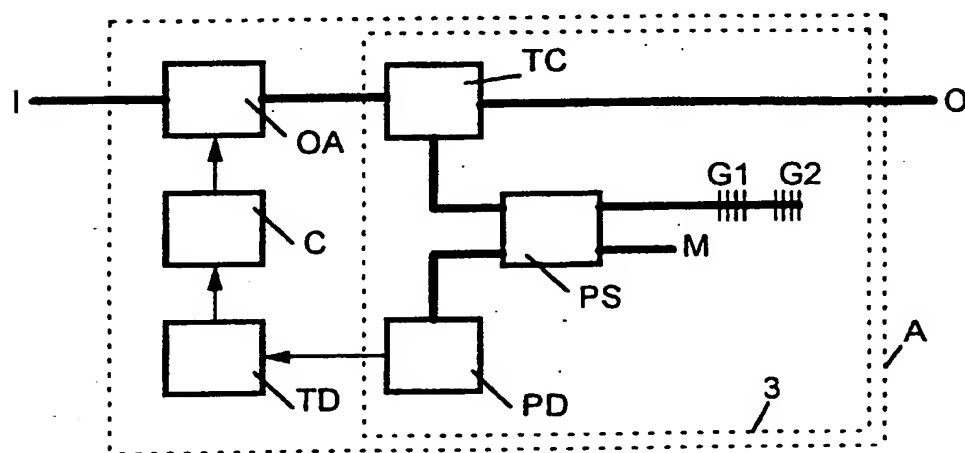


Fig. 4

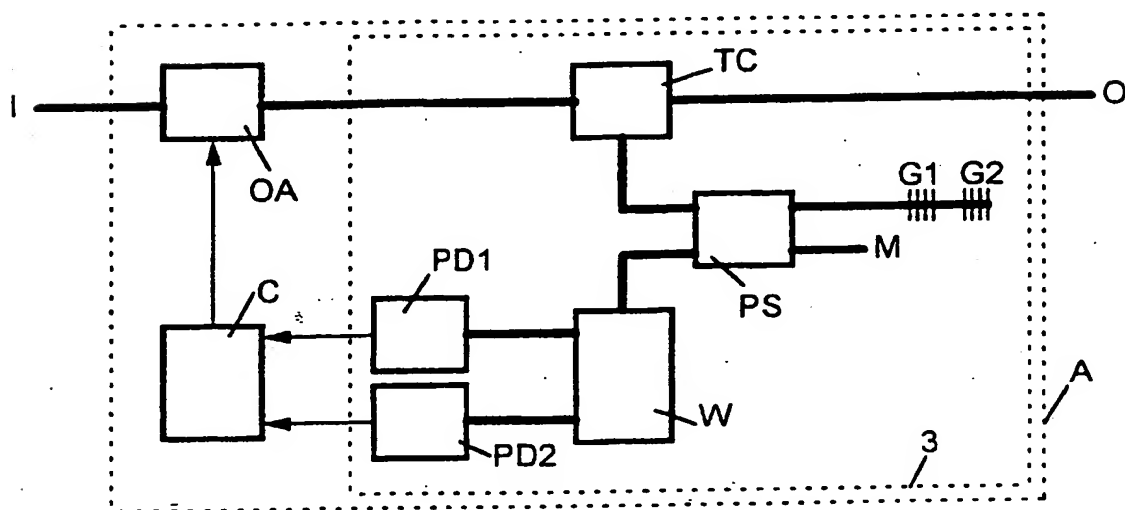


Fig. 5

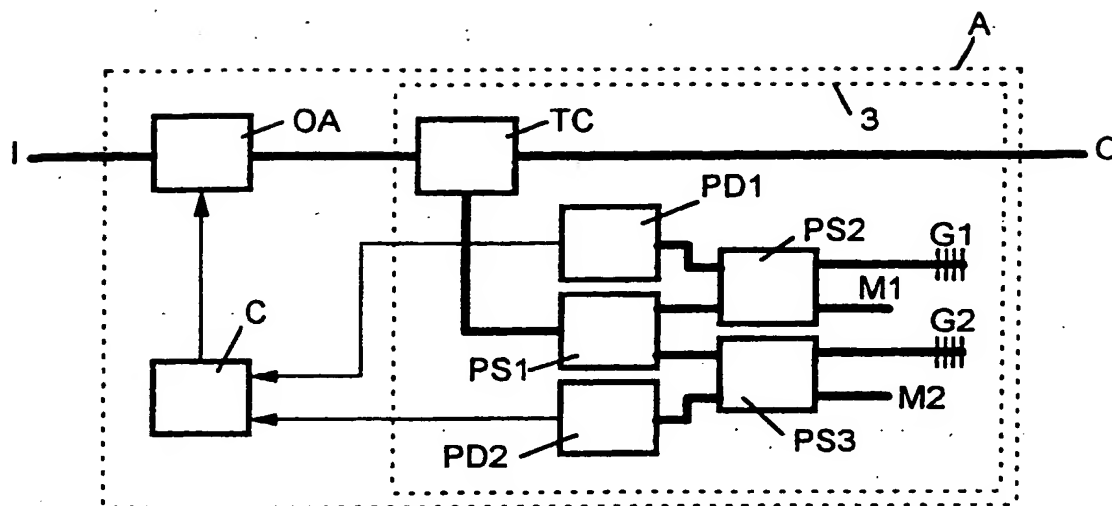


Fig. 6

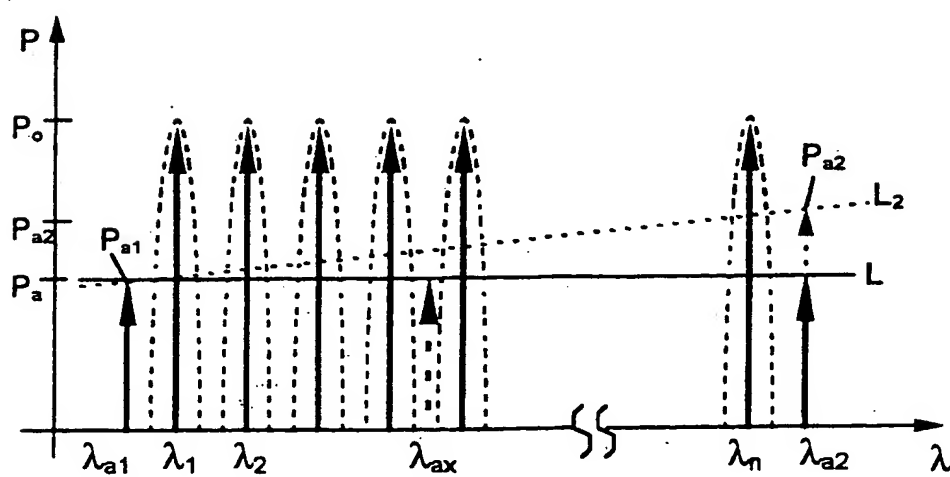


Fig. 7



European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 98 30 0561

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.CI.6)
A	EP 0 663 738 A (ALCATEL NV) 19 July 1995 * abstract * * column 1, line 1 - line 34 * * column 2, line 54 - column 4, line 53 * ----	1,6	H04J14/02
A	EP 0 467 396 A (CANON KK) 22 January 1992 * abstract * * column 5, line 7 - line 27 * * column 6, line 18 - line 28 * ----	1,6	
A	WO 97 06616 A (STC SUBMARINE SYSTEMS LTD; JONES KEVAN PETER; WALL DAVID JAMES) 20 February 1997 * page 3, line 17 - page 4, line 6 * * page 5, line 2 - line 12 * * page 6, line 5 - page 7, line 7 * ----	1,6	
A	EP 0 769 861 A (NIPPON ELECTRIC CO) 23 April 1997 * abstract * -----	1,6	
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (Int.CI.6)
			H04J
Place of search	Date of completion of the search	Examiner	
THE HAGUE	15 June 1998	Chauvet, C	
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 98 30 0561

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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15-06-1998

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